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THE LIQUID-AIR SYSTEM AND THE DRY-ICE COOLING SYSTEM: A FIELD T--ETC(U)
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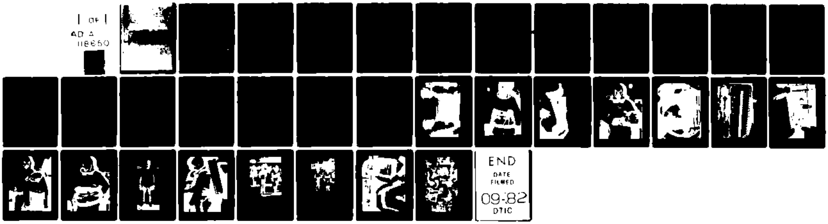

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Navy Clothing and Textile Research Facility (NCTRF) conducted a field evaluation to compare two life-support-suit assemblies. One assembly was a liquid-air-cooled suit that provided convective cooling; the other was a dry-ice system that used liquid-cooled underwear to provide conductive cooling. The test results indicated the dry-ice system was preferred by 74.2% of the test subjects for cooling purposes. (U)

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

The Liquid-Air System and the Dry-Ice Cooling System:
A Field Test of the Cooling Capabilities of
Two Life-Support-Suit Assemblies

INTRODUCTION

In August 1980, the Navy Clothing and Textile Research Facility (NCTRF) conducted a field evaluation test of the cooling capabilities of two life-support-suit assemblies at the Naval Explosive Ordnance Disposal Technology Center (NAVEODTECHCEN), Indian Head, Maryland. The two assemblies were:

a. A self-contained backpack and suit/helmet ensemble (Figure 1, left), which utilized liquid air to provide breathing air and convective cooling to the body and head.

b. A modified suit and helmet similar to (a) above, which was altered to accommodate liquid-cooled underwear. A dry-ice cooling backpack supplied the chilled coolant to the underwear, which provided conductive cooling to the body and head (Figure 1, right). This backpack was developed by NCTRF to alleviate heat stress with a variety of protective clothing (1).

The test sequence consisted of dressing two test subjects, one in each of the two suit assemblies, and exercising them under moderate to heavy workloads outdoors in the morning. The subjects exchanged suits in the afternoon and repeated the same exercise condition. Six test subjects were used during the testing period. Since the NCTRF dry-ice cooling system (DICS) did not provide an internal breathing supply, the test subjects were forced to breathe through an emergency breathing device similar to a skindiver's mouthpiece. This placed an additional load (psychological) on the subject exercising in this suit.

The results of the testing showed that the DICS was the choice of 74.2% of the subjects for cooling purposes. This report describes the two suit assemblies, the test procedures, and the test results.

SUIT ASSEMBLY DESCRIPTION

Liquid-Air Suit (LAS)

The liquid-air suit (LAS) is a two-piece (upper torso and lower torso) assembly (Figure 2) with a zipper and triple seal around the waist and with detachable sealed boots (Figure 3) and gloves. The helmet, which is also detachable (Figure 4), is fitted with cooling and breathing air-distribution systems and with an emergency breathing mouthpiece connected to outside air by way of suitable check valves and charcoal filters. The upper torso has a built-in frame and harness (Figure 5) to support the liquid-air backpack and quick-disconnect air ducts to route cooling air to the extremities. The liquid-air backpack (Figure 6) is latched onto the suit pack frame when ready for use (Figure 7) and has an integral suit-pack interface gas connector, which functions automatically as the pack is removed or installed. The pack provides cooling and breathing air to the suit and maintains a slight positive pressure in the suit with a relief valve in the torso. Liquid air for the pack is supplied from a fixed-base cryogenic generator.

(1) Audet, Norman F., and Orner, George M., Dry-Ice, Liquid-Pulse-Pump, Portable Cooling System, NCTRF Technical Report No. 131, January 1980.

Dry-Ice Cooling System (DICS)

The helmet and outer shell portion of the suit (Figures 8 and 9) was a modified LAS. The backpack frame and harness and the air ducts were removed, the resultant hole patched, and feed throughs for the liquid lines installed. A commercially available liquid-cooled garment (LCG) (Figure 10) was provided with quick disconnects to attach to the inner side of the shell. This LCG (in the form of long-johns with a hood) provided conductive cooling to the torso and head with a coolant of methanol-water. The coolant was provided by the backpack (Figure 11), which was attached to the outer shell with harness straps. Mating quick disconnects were provided on the outside of the shell and backpack for the coolant supply and return lines.

The pack contained a diaphragm pump to circulate the coolant, a bypass valve to regulate the cooling, suitable check and relief valves, and a combination dry-ice canister and heat exchanger. The canister assembly had an inner and outer wall and bottom between which the coolant flowed and produced heat transfer with the dry ice. The canister had a removable lid with relief valve, burst disc, and gasline. Dry ice was pulverized and compacted in the canister and the lid was reinstalled. Besides providing the cooling medium for the methanol mixture, the gaseous carbon dioxide given off by sublimation of the dry ice drove the coolant pump.

Since this suit assembly did not provide breathing air, the emergency breathing mouthpiece built into the helmet was used. Using this mouthpiece (similar to an aqualung mouthpiece) tended to add extra stress to the subject when exercising in this suit.

TEST DESCRIPTION

The test procedure was to have the suited volunteer perform a typical task or tasks that would be done by explosive ordnance disposal personnel in an emergency condition. (See Table I for the physical characteristics of the test subjects and the number of tests completed.) The tasks suggested by NAVEODTECHCEN personnel were walking distances of 1.4 miles and 1.8 miles. Both walks involved climbing a 150-yard incline. The longer walk (with a steeper incline) was designated as a heavy stress exercise, and the shorter walk a moderate stress exercise. Both walks occurred on blacktop roads and generally in direct sunlight. The ambient temperatures (°F) were generally in the low 80's in the morning tests and the mid 90's in the afternoon tests.

Table I. Physical Characteristics of Test Subjects and Number of Tests

Name	Age	Nude Wt. (kg.)	Height (m)	Body A (m^2)	Number of tests LAS	DICS
R. J.	26	76.09	1.727	1.89	3	3
C. S.	19	60.82	1.803	1.78	2	3
J. B.	31	96.64	1.829	2.18	1	1
J. C.	31	81.48	1.765	1.98	4	4
A. P.	30	80.71	1.829	2.02	1	1
R. B.	31	55.78	1.702	1.64	3	3

The moderate level exercise consisted of departing the locker room when suited up (Figure 12), walking 0.7 miles with the downhill slope at the end (Figure 13), resting 5 minutes (Figure 14), then returning to the locker room. After another 5-minute rest, two laps around the barn, then a short walk through a grassy field with a short climb down and up a grassy slope (Figure 15) completed the exercise. The sequence generally took 1 hour.

The heavy load exercise consisted of departing the locker room, walking 0.8 mile with a steeper uphill incline at the end followed by a 5-minute rest. After resting, the subjects returned by the same route, pausing to walk up and down an 8-foot-high shooting-range tower twice before returning to the locker room. This sequence also lasted 1 hour. Before and after each exercise, a series of questionnaires were completed and blood pressures and weights obtained. The detailed sequence is presented in Appendix A.

Eight days were allotted for tests, with both suits being used in the morning and afternoon. On the last day, the morning and afternoon runs were of a different nature. (In Tables II and III, these tests are designated as "Scenario.") Dummy ordnances were buried in the woods and the subjects were to retrieve them. They dressed outside, operating from a truck. Then they marched through the woods carrying a shovel and ordnance containers to the burial site. After a 5-minute rest, the subjects dug up the devices, packaged them, and returned to the starting point with tools and dummy weapons.

Because liquid air was not available on the first day of the testing, only the DICS was run in the morning and afternoon. On the second day of testing, the morning run with the DICS was aborted because of pack malfunction. The problem was found to be the lid of the heat exchanger canister being insufficiently tightened to maintain internal pressure. All other test runs were completed.

TEST RESULTS

The total number of tests was 15 for the DICS and 14 for the LAS. The scheduling produced a fairly even spread of three tests for each suit under both moderate and heavy workloads and in morning and afternoon heat loads. (See Tables II and III.) With only six test subjects involved (all with different metabolisms) and the limited number of tests, it would be invalid to give a realistic subject weight loss figure. We can say only that, while exercising in the LAS, the subjects lost significantly more weight than under comparable conditions in the DICS. (See Tables II and III.) It can also be seen that the oral temperatures, both overall and during exercise, were lower in the DICS than in the LAS. This is to be expected, since the majority of the heat transfer in the LAS is by evaporative cooling.

Question 11 of Appendix B shows 47.8% of the subjects preferred the DICS (vs 30.4% for the LAS). Meanwhile, 73.9% said the DICS gave the most effective cooling (vs 13.5% for the LAS), and 86.9% stated the DICS gave effective cooling for the longest period (vs 8.7% for the LAS). (See Appendix B, Questions 11a and 11b.) From the comments on the individual questionnaires, it was obvious that, had the subjects not been required to breathe through a mouthpiece when in the DICS, they would have been more partial towards the DICS. The control valve for the DICS backpack did not give the user enough variation between maximum and minimum cooling. Observers noted that, while exercising in the DICS, the subjects tended to leave the valve in the full-open position, rather than search for an intermediate setting.

Table II. Physiological Parameters of the Liquid-Air Suit

Date and Subject's Name	Δ Nude Wt. Kg.	Δ Suited Wt. No Pack Kg.	Δ Oral Temp Overall °C	Δ Oral Temp Exercise °C	Amount of Liq. Air Packed Kg	Left Kg	Used Kg	Time of Testing (Exercise) Min.
AM Moderate W/Load								
8/6/80 C. S.	0.11	0.23*	+0.9	+1.2	5.40	2.19	3.21	64.00
8/8/80 R. J.	0.40	0.29	+1.1	+0.4	6.08	2.57	3.51	67.00
8/13/80 A. P.	0.57	0.23	+0.1	+0.0	6.02	3.04	2.98	60.00
Average	0.36	0.25	+0.7	+0.5	5.83	2.60	3.23	64.00
PM Moderate W/Load								
8/6/80 R. J.	0.45	0.34	+0.6	0.0	5.85	2.28	3.57	67.00
8/8/80 J. B.	1.14	0.23	+0.0	+0.1	6.16	2.79	3.37	66.00
8/13/80 J. C.	0.34	0.22	+0.9	+0.4	6.08	2.85	3.23	60.00
Average	0.64	0.26	+0.5	+0.2	6.03	2.64	3.39	64.00
AM Heavy W/Load								
8/7/80 C. S.	0.23	0.23	+0.8	+1.3	6.41	2.97	3.44	60.00
8/11/80 R. B.	0.68	0.34	+0.8	+0.9	5.76	2.68	3.08	60.00
8/12/80 J. C.	0.68	0.24	+0.1	+0.2	6.37	3.36	3.01	60.00
Average	0.53	0.27	+0.6	+0.8	6.18	3.00	3.18	60.00
PM Heavy W/Load								
8/7/80 R. J.	0.45	0.23	+1.4	+1.3	6.40	3.14	3.26	60.00
8/7/80 J. C.	1.36	0.34	+0.2	+1.0	5.77	2.62	3.15	55.00
8/12/80 R. B.	0.34	0.40*	+0.6	+0.8	6.54	3.21	3.33	55.00
Average	0.72	0.32	+0.7	+1.0	6.24	2.99	3.25	57.00
Scenario								
AM 8/14/80 J.C.	-	-	-	0.0	full	-	-	40.00
PM 8/14/80 R. B.	-	-	+0.5	+0.4	full	-	-	40.00

Δ Difference between starting and finishing weights or temperatures.

* Because of the type of measuring devices at our disposal, Health-O-Matic made by Continental Scale Co., Model 400 ACD, accuracy to 1/4 lb (.12Kg) increments, it was difficult to get a very accurate weighing. Some discrepancy may be seen in the readings on the Δ of nude and clothed weights and the above would account for those erroneous readings.

Table III. Physiological Parameters of the Liquid-Cooling Garment

Date and Subject's Name	Δ Nude Wt. Kg.	Δ Suited Wt. No Pack Kg.	Δ Oral Temp Overall °C	Δ Oral Temp Exercise °C	Amount of Dry Ice Packed Kg	Amount of Dry Ice Left Kg	Amount of Dry Ice Used Kg	Time of Testing (Exercise) Min
AM Moderate W/Load								
8/5/80 R. J.	0.17	0.22*	0.00	-0.20	4.74	.65	4.09	61.00
8/8/80 J. B.	0.46	0.01	0.00	-0.20	4.39	1.21	3.18	71.00
8/13/80 J. C.	0.28	0.06	-0.40	-0.10	4.35	1.23	3.12	64.00
Average	0.30	0.10	-0.10	-0.16	4.49	1.03	3.46	66.00
PM Moderate W/Load								
8/5/80 C. S.	0.45	0.00	+0.60	+0.00	4.16	.28	3.88	70.00
8/6/80 C. S.	0.31	0.11	+0.60	+0.40	4.51	1.14	3.37	65.00
8/8/80 R. J.	0.17	0.00	+0.10	-0.20	4.51	.31	4.20	62.00
8/13/80 A. P.	0.37	0.23	-0.20	0.00	4.44	1.24	3.20	60.00
Average	0.21	0.08	+0.28	+0.10	4.41	0.74	3.66	64.00
AM Heavy W/Load								
8/11/80 J. C.	0.74	0.17	0.00	+0.30	4.71	1.03	3.68	70.00
8/7/80 R. J.	0.11	0.00	+0.30	+0.20	4.74	0.43	4.31	61.00
8/12/80 R. B.	0.34	0.28	+0.50	+0.40	4.59	2.22	2.37	50.00
Average	0.40	0.15	+0.27	+0.30	4.68	1.23	3.45	61.00
PM Heavy W/Load								
8/7/80 C. S.	0.11	0.06	+0.60	+0.70	4.67	1.12	3.55	60.00
8/11/80 R. B.	0.34	0.00	+0.60	+0.30	4.44	1.70	2.74	60.00
8/12/80 J. C.	0.11	0.00	+0.20	+0.50	4.57	1.50	3.07	55.00
Average	0.19	0.02	+0.46	+0.50	4.56	1.44	3.12	59.00
Scenario								
AM 8/14/80 R. B.	-	-	+0.40	+0.10	Full	1/2 left	-	43.00
PM 8/14/80 J. C.	-	-	+1.00	+0.10	Full	1/2 left	-	49.00

* Because of the type of measuring devices at our disposal, Health-O-Matic made by Continental Scale Co., Model 400 ACD, accuracy to 1/4 lb (.12 Kg) increments, it was difficult to get a very accurate weighing. Some discrepancy may be seen in the readings on the Δ of nude and clothed weights and the above would account for those erroneous readings.

With a normal 1-hour test run, there was typically 25% of the dry ice remaining at the completion of the test. For the 1-hour test with the liquid-air system, 46% of the liquid air remained.

CONCLUSIONS

From the comments of the test subjects and the observation of the test monitors, the DICS appears superior to the LAS suit under moderate to heavy workloads. The dry ice required for the liquid-cooled suit is widely available or may be generated from liquid carbon dioxide in bottles or shipboard fire-fighting supplies. The liquid air, on the other hand, is produced only by a large fixed-base cryogenerator and is not commercially available. The simplicity of the DICS overcomes the logistics problem commonly seen with other systems. As shown, the DICS can easily be adapted to existing air-cooled systems or to suit assemblies presently having no cooling capabilities. For adaption to suit systems that require a self-contained breathing supply, commercial breathing assemblies are currently available to supplement the DICS.

APPENDIX A.

TEST PROCEDURES AT NAVEODTECHCEN

Pretest Preparations

LAS	DICS
1. Wt. of Suit and Helmet	1. Wt. of Suit and Helmet
2. Wet and Weigh Long Underwear	2. Wt. of Liquid Cooling Garment
3. Weigh Liquid Air Pack (Full)	3. Cylinder Wt. without Dry Ice
	4. Cylinder Wt. with Dry Ice
	5. Pack Wt. Only
	6. Wt. of Pack and Cylinder with Dry Ice

At the end of the test, these weights were taken again for comparison.

When the test volunteers entered the test preparation room, they were allowed 10 minutes to relax after which the following events took place.

1. Daily questionnaires with questions such as: Time to bed, time arose, illnesses past and present, any recent medications, and how the subjects generally felt that day.

2. Oral temperature.

3. Blood pressure.

4. Nude weight.

5. Depending on the suit to be worn, the volunteers would put on either the liquid-cooling garment over their own underwear (boxer shorts, tee shirts, socks), or, in the case of the liquid-air suit, the presoaked long underwear.

6. Another oral temperature was taken.

7. Volunteers were timed donning their appropriate suits.

8. Suited weight with helmet but no backpack.

9. Backpacks were donned.

10. The entire system was weighed.

11. Another oral temperature was taken.

12. The system was started and helmets were donned.

NOTE: At this point the test officially started.

13. The volunteers were escorted from the air conditioning room to the outside where the monitor recorded:

a. How volunteers felt
b. Ambient temperature
c. Humidity
d. Type of day (sunny, overcast, etc.)

14. The test exercise began and the monitor recorded conditions every 5 minutes. The test ran for 1 hour with either a heavy or a moderate workload.

15. After the exercise, the volunteers returned to the building of departure. Again the monitor recorded a, b, c, and d as in #13.

16. Once the subjects were inside the air conditioning room, another total weight was taken.

17. The helmet was removed and another oral temperature was taken.

18. The backpacks were removed and weighed.

19. Another suited weight without backpack was taken.

20. The suits were removed and weighed (time for removal of suit taken).

21. Oral temperature was taken.

22. Underwear was removed and weighed.

23. A final nude weight was taken.

24. A final oral temperature was taken.

25. A final blood pressure was taken.

26. The volunteers were given a comment sheet to fill out.

27. The volunteers were released from the test.

APPENDIX B. Test Subjects' Comments on the Two Cooling Systems

Question	Dry-Ice Cooling System (DICS)			Liquid-Air System (LAS)			Remarks
1. Number of Tests	15			14			Dry Ice - had one mechanical failure. Liquid Air - missed a day because of no liquid air.
2. Donning Suit	Good 13--86.8%	Fair 2--13.2%	Poor -	Good 12--85.7%	Fair 2--14.3%	Poor -	Both complained of fitting at shoulders.
3. Complete System Fit	Good 10--66.7%	Fair 4--26.7%	Poor 1--6.6%	Good 11--78.6%	Fair -	Poor 3--21.4%	Most common complaint was due to helmet.
4. Fit of Chemical-Agent Protective Clothing	Tight 2--14.3%	Comfortable 9--64.3%	Loose 3--21.4%	Tight -	Comfortable 11--78.6%	Loose 3--21.4%	DICS - helmet tight. LAS - Skin irritation aused by improper fit (too big).
5. Fit of Test Garments		Comfortable 15--100%					Proper fit is important.
6. a) Fit of Back-Pack Systems	Uncomfortable 1--6.6%	Comfortable 13--86.8%	Secure 1--6.6%	Uncomfortable -	Comfortable 11--78.6%	Secure 3--21.4%	DICS - Proper fit of pack is important. Uncomfortable due to neck ring and helmet hitting back pack. LAS - Subject had to keep adjusting pack from slipping down.
b) BackPack Harness							
1. Securing of Pack to Body	Excellent 1--6.6%	Good 13--86.8%	Fair 1--6.6%	Excellent -	Good 10--71.4%	Fair 4--28.6%	LAS - Same as above.

APPENDIX B (cont'd)

Question	Dry-Ice Cooling System (DICS)	Liquid-Air System (LAS)	Remarks
2. Comfort to Shoulder, Chest, and Back	Comfortable 14--93.4%; Uncomfortable 1--6.6%	Comfortable 9--69.2%; Uncomfortable 4--30.8%	DICS - Proper fit is important. LAS - Shoulder straps dig in and pack kept slipping, causing a stooped-over position.
c) Weight	Heavy -; Moderate 15--100%; Light -	Heavy 5--38.5%; Moderate 8--61.5%; Light -	DICS - On scenario the weight did not restrict the mission. LAS - After moderate work, pack felt heavy.
d) Weight Distribution on Body	Good 10--66.7%; Fair 4--26.7%; Poor 1--6.6%	Good 10--83.3%; Fair 2--16.7%; Poor -	DICS - Fit important at Helmet-neck-ring area & at shoulder-strap area. LAS - Same comments on pack as before.
7. Entire Cooling of System	Comfortable 15--100%	Comfortable 9--69.2%; Too Warm 3--23.1%; Hot 1--7.7%	DICS - Some felt face, hands and feet got warm. LAS - Suit cool while subjects at rest, but once working they would warm up.
8. See Appendix C			
9. Regulation of Control on Back-Pack (Dry-Ice System only)	Ease 3--21.4%; Some Difficulty 7--50%; Very Difficult 3--21.4%; Not at all 1--7.2%	N/A	Sometimes couldn't get control position just right. Once position was found, subjects were OK and, with experience, could find a good control position.

APPENDIX B (cont'd)

Question	Dry-Ice Cooling System (DICS)	Liquid-Air System (LAS)	Remarks
10. Cooling regulation with the control valve was	Good 12--80.2%; Fair 2--13.2%; Poor 1--6.6%	N/A	Same as 9.
11. Which system do you prefer?	11 of 23--47.8%	7 of 23--30.5%	Either System 5 of 23--21.7%
a) Most Effective Cooling?	17 of 23--74.2%	3 of 23--12.9%	3 of 23--12.9%
b) Effective cooling for longest period?	20 of 23--87.1%	2 of 23--8.6%	1 of 23--4.3%
12. Would you object to wearing either of these systems if adopted?	No 13; Yes 2	No 11; Yes 2	----

APPENDIX C. Sectional Comparison of the Two Cooling Systems

8. Is there any one section of the cooling system that keeps you cooler or warmer than another?

DRY-ICE COOLING SYSTEM (DICS)

MODERATE WORKLOAD

	AM			PM		
	Avg. Temperature--82°			Avg. Temperature--93.3°		
	Avg. Humidity--71.3%			Avg. Humidity--51.8%		
	Cool	Warm	Comfortable	Cool	Warm	Comfortable
Head		3			1	3
Arms			3	3		1
Torso						
(1) Front	1		2	3		1
(2) Back	1		2	1		3
Legs	1		2	2		2

Comments: Feet, hands, & face were warm at times.

Comments: Face, sweating & warm; Feet and hands stay warm in sun.

HEAVY WORKLOAD

	AM			PM		
	Avg. Temperature--81°			Avg. Temperature--92.5°		
	Avg. Humidity--75.6%			Avg. Humidity--61.0%		
	Cool	Warm	Comfortable	Cool	Warm	Comfortable
Head		2	2		2	2
Arms	2		2	2		2
Torso						
(1) Front	2		2	2		2
(2) Back	3		1	3		1
Legs	3		1	3		1

Comments: Generally the same as above.

8. Is there any one section of the cooling system that keeps you cooler or warmer than another?

LIQUID-AIR SYSTEM (LAS)

MODERATE WORKLOAD

AM

Avg. Temperature--82°
Avg. Humidity--71.3%

PM

Avg. Temperature--93.3°
Avg. Humidity--51.8%

	AM Cool	AM Warm	AM Comfortable	PM Cool	PM Warm	PM Comfortable
Head	1		2	1		2
Arms		1	2			3
Torso						
(1) Front		1	2		2	1
(2) Back		1	2		2	1
Legs		2	1		1	2

AM Comments: None.

PM Comments: Feet & fingertips warm, sometimes hot.

HEAVY WORKLOAD

AM

Avg. Temperature--80.6°
Avg. Humidity--75.8%

PM

Avg. Temperature--92.5°
Avg. Humidity--61.3%

	AM Cool	AM Warm	AM Comfortable	PM Cool	PM Warm	PM Comfortable
Head	2		2	2		2
Arms		2	2		2	2
Torso						
(1) Front		3	1		3	1
(2) Back		3	1		3	1
Legs		3	1		3	1

AM Comments: None.

PM Comments: Body comfort not uniform at end of test.

APPENDIX D. ILLUSTRATIONS

Figure 1. A Self-Contained Backpack and Suit/Helmet Ensemble Using Liquid Air (left) and a Modified Suit and Helmet With a Dry-Ice Cooling Backpack (right).

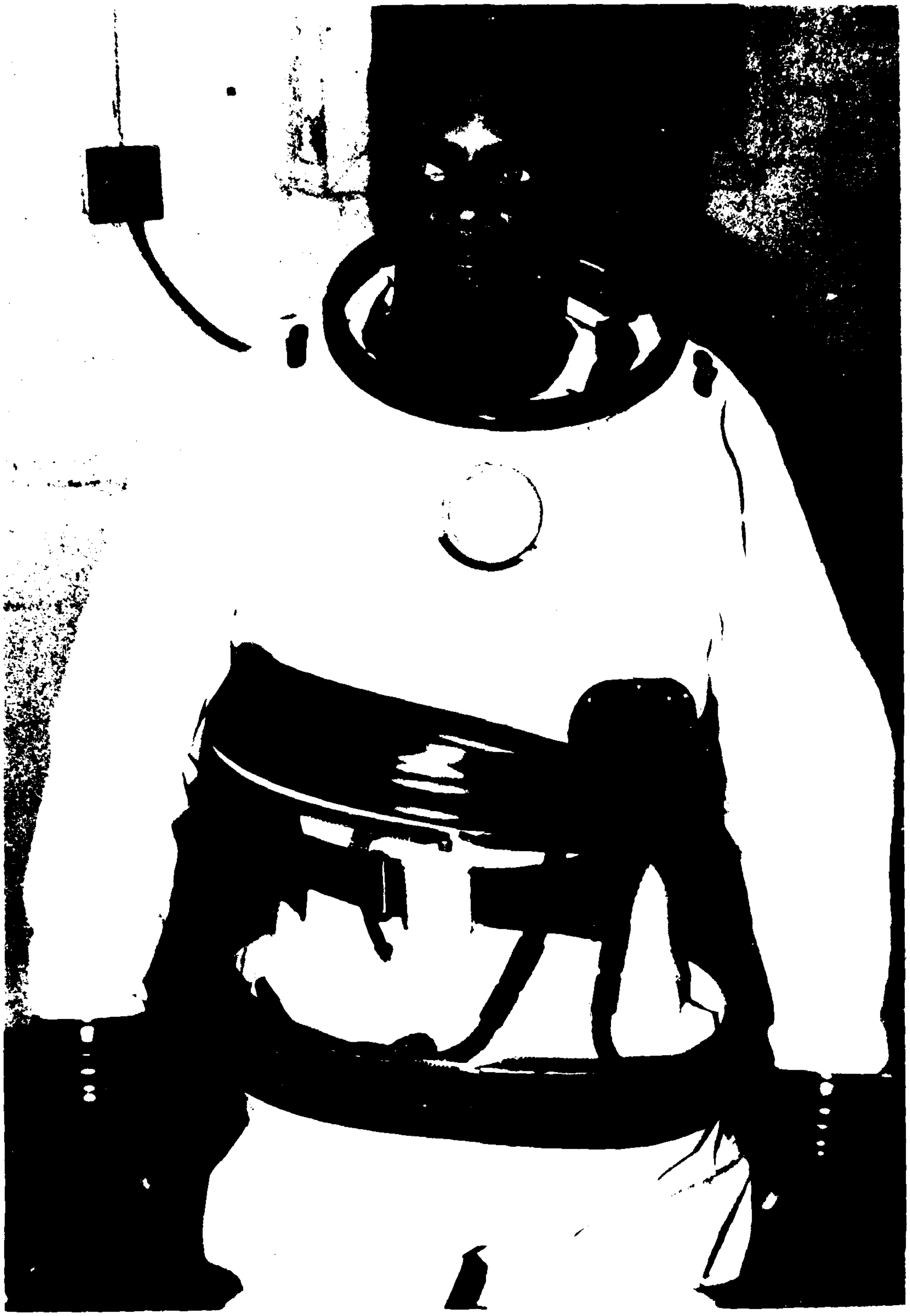

Figure 2. The Two-Piece Liquid-Air Suit.

Figure 3. The Detachable Sealed Boot Worn With the Liquid-Air Suit.

Figure 4. The Detachable Helmet Worn With the Liquid-Air Suit.

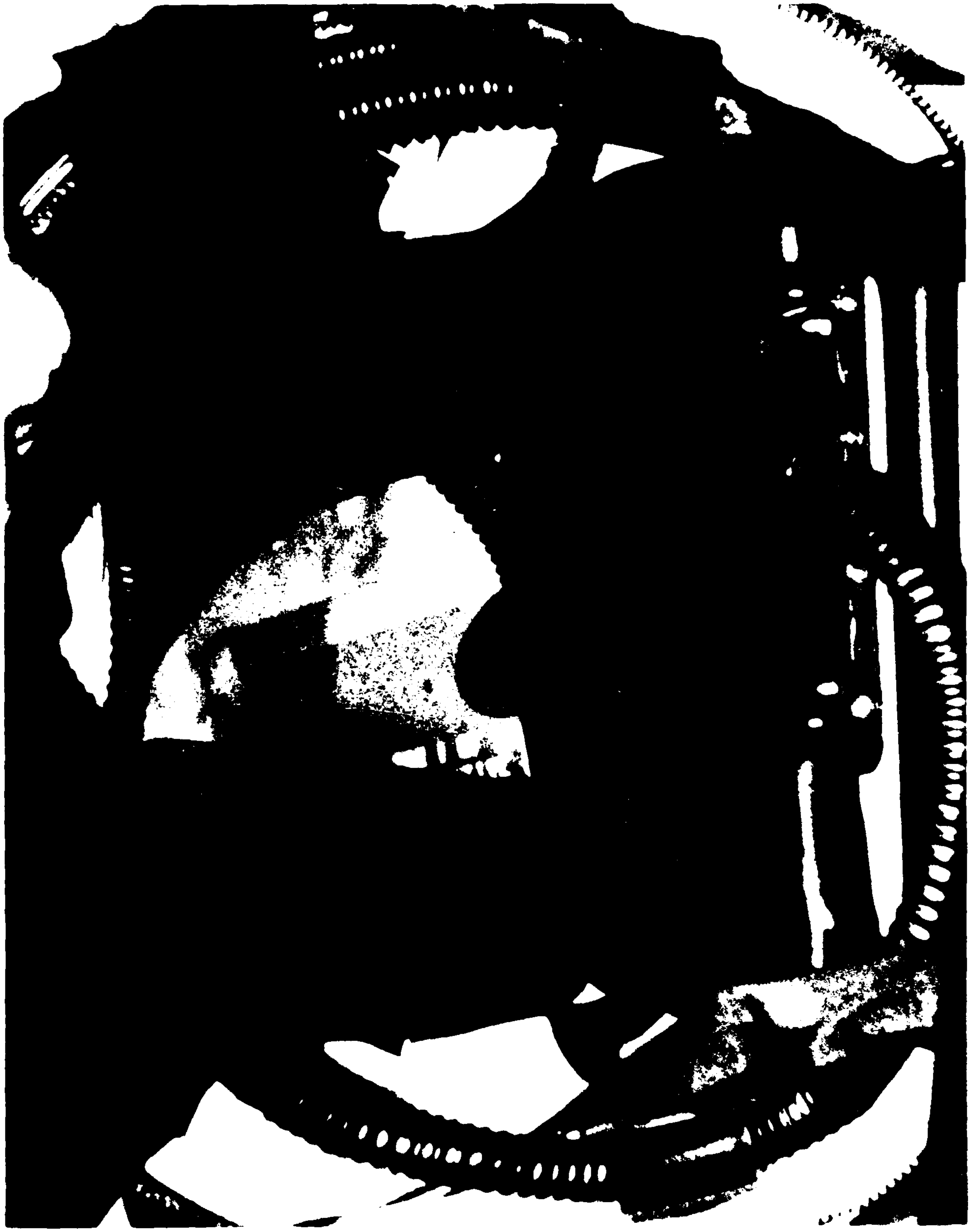

Figure 5. The Frame and Harness Contained in the Upper Torso of the Liquid-Air Suit.

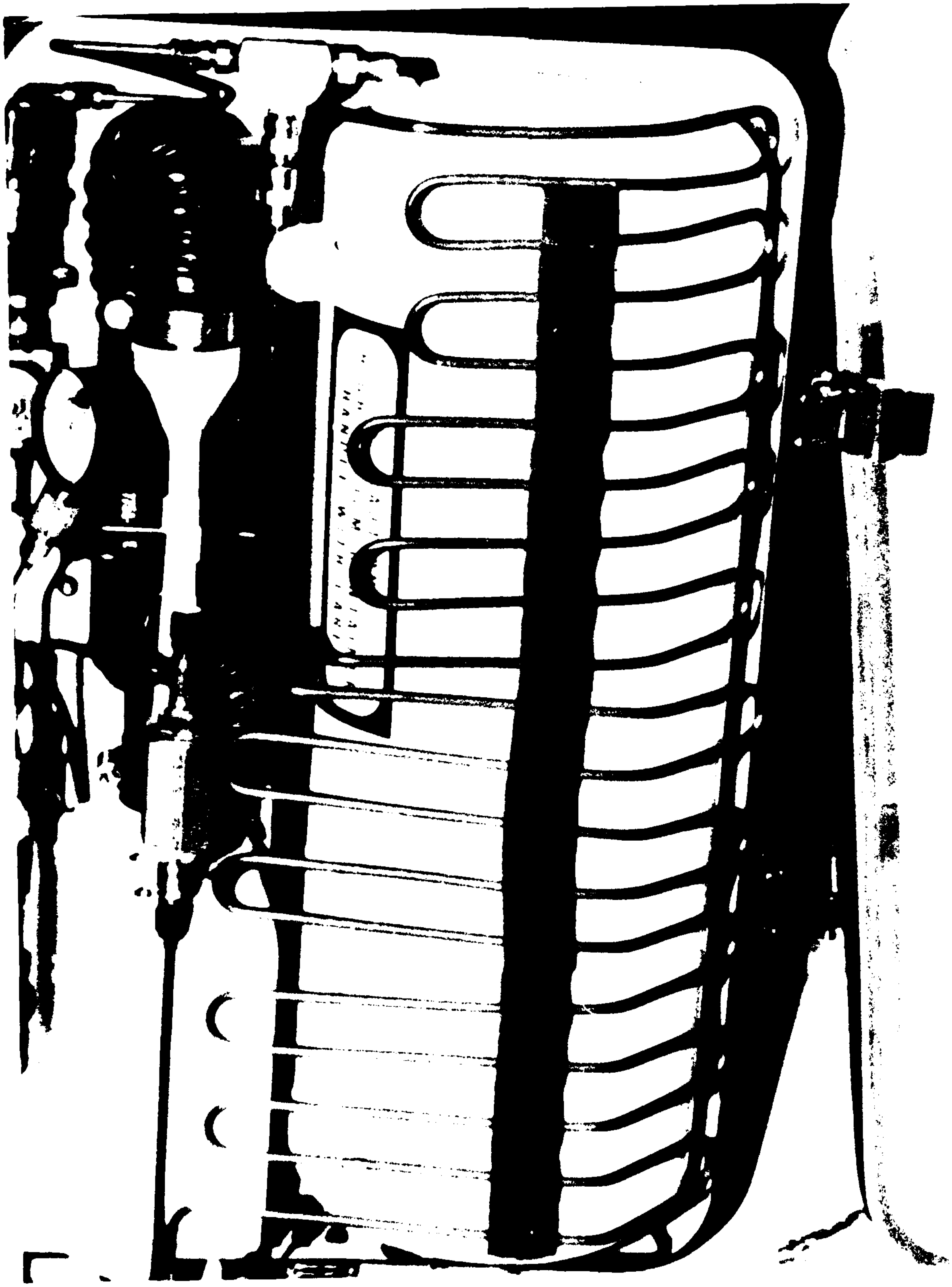

Figure 6. Internal View of the Liquid-Air Backpack.

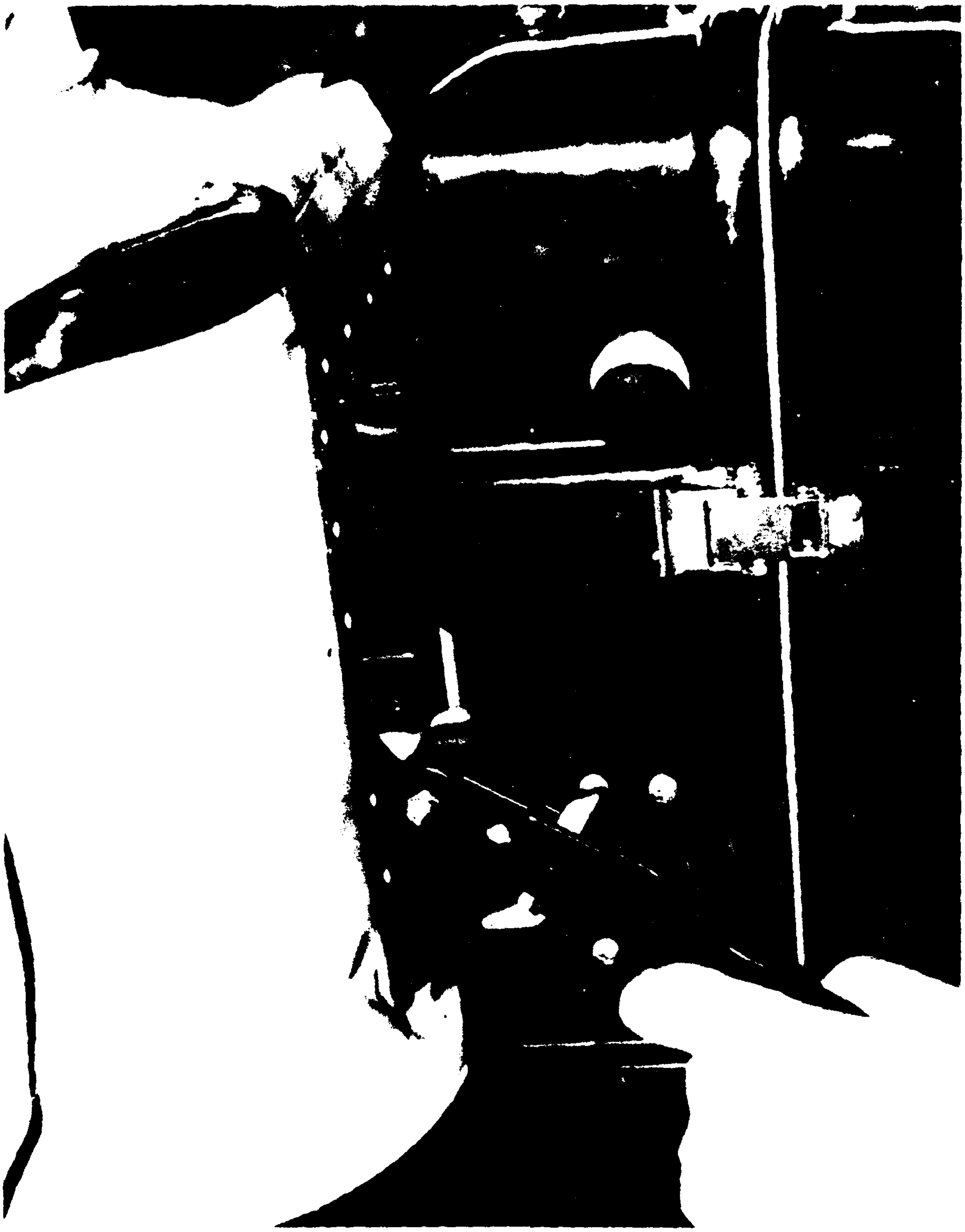

Figure 7. The Liquid-Air Backpack Being Latched Onto the Suit Pack Frame.

Figure 8. The Liquid-Cooled Garment (LCG) and the Modified Outer Shell of the Suit Worn With the Dry-Ice Backpack.

Figure 9. A Test Subject Dons the Modified Two-Piece Suit.

Figure 10. Front View of the Liquid-Cooled Garment (LCG).

Figure 11. The Dry-Ice Backpack Being Attached to the Outer Shell.

Figure 12. Test Subjects and Monitors After Leaving the Locker Room.

Figure 13. Subjects Walk Downhill During the Test.

Figure 14. Test Subjects During 5-Minute Rest Period.

Figure 15. Test Subjects Walk Uphill to Complete Their Exercise.

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82